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Research Article (Subject – Palynology)

Palynology of the Cretaceous-Tertiary Sedimentary Succession of Sile Well, Offshore Dahomey Basin, Benin Republic

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Abstract

The sedimentary succession penetrated by the Sile Well offshore Benin republic in the Dahomey basin has been investigated using palynofossils. Studied sedimentary succession consists from base to top of limestone, sandstone and shale having a total thickness of approximately 2000m. Palynological study recorded a total of 19 pollens, 8 spores, 20 dinoflagellates and one algae species. Two palynozones A1 (1640-1720) and A2 (1340-1640) were identified and demarcated based on occurrence of characteristic palynofossils. Ternary plot of palynomorphs and Palynomorph Marine Index (PMI) suggest the depositional environment of freshwater through brackish to shallow marine environment. This work constitutes a significant contribution to the understanding of the palynostratigraphy of Dahomey Basin, which is currently the focus of intensive hydrocarbon exploration activities in Nigeria. These findings may help in efficient exploration activities utilizing depositional paleoenvironment information on deposition of petroleum system elements in time and space in the region.

Keywords: Palynology, Depositional environment, Maastrichtian, Eocene, Dahomey Basin, Benin Republic.

Introduction

The Dahomey (Benin embayment) Basin is an extensive basin located in West Africa (Fig. 1). It covers much of the continental margin of the Gulf of Guinea, extending from Volta-delta in Ghana through Togo and Republic of Benin to southwestern Nigeria, where it is separated from and cut off by stratigraphically younger Niger Delta. Dahomey Basin is a marginal pull-apart basin or marginal sag basin which was developed as the African and South American lithospheric plates separated in the

Mesozoic and continental margin was formed. The aim of this study is to investigate the palynology in order to know the occurrence, distribution and diversity of the assessment of different species, construction of the different biozonations of the fossils recovered from the sediments and assessment of the ecology and dwelling environment of the different fossils forms in the sediments.

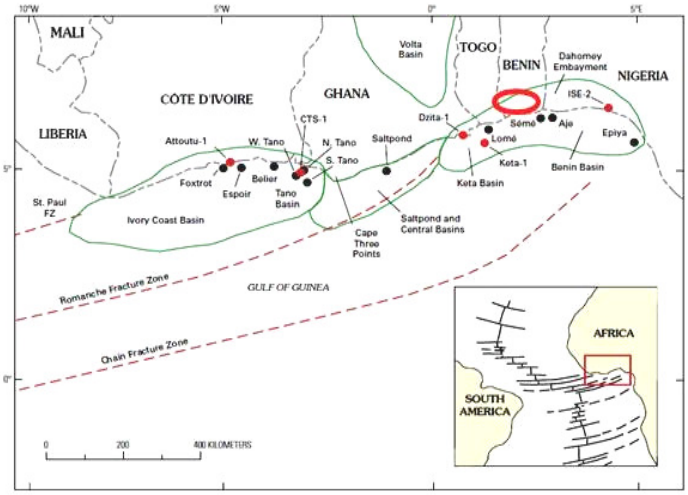

Fig. 1. Regional map of Dahomey Basin showing location of Sile Well.

Earlier studies interpreted palynofloras from the Akinbo Formation (corresponding to the lower part of the Oshosun Formation) as late Paleocene to early Eocene. Alves et al. (2005) having worked on the palynofacies and nanofossils from cored well section of the Araromi Formation onshore in southern Nigeria reported that the palynofacies was dominated by palynomorphs mainly dinoflagellates and amorphous organic matter of algal origin. This they opined indicated open marine settings. Again, from the palynofacies distribution patterns they inferred depositional environments which ranged from a very proximal oxic shelf to a distal dysoxic-anoxic deep-water environment. The calcareous nanofossil biostratigraphy indicated a Late Cretaceous (Maastrichtian) to early Eocene age. They further noted variable nanofossil abundance, diversity and preservation throughout the section they studied.

AGE		FORMATION		LITHOLOGY
		Ako et al., 1980	Omatsola and Adegoke, 1981	
TERTIARY	EOCENE	ILARO FORMATION	ILARO FORMATION	SANDSTONE
		OSHOSUN FORMATION	OSHOSUN FORMATION	SHALE
		AKINBO FORMATION	AKINBO FORMATION	
	PALEOCENE	EWEKORO FORMATION	EWEKORO FORMATION	LIMESTONE
CRETACEOUS	MAASTRICHTIAN	ABEOKUTA FORMATION	ABEOKUTA GROUP: ARAROMI FORMATION	SHALE
	TURONIAN		AFOWO FORMATION	SANDSTONE AND SHALE
	BARREMIAN		ISE FORMATION	SANDSTONE

Fig. 2. Stratigraphy of the Dahomey Basin.

Bankole et al. (2007) used palynomorphs to deduce age and paleoenvironment of the newly exposed section of the Oshosun Formation at Shagamu quarry, Dahomey Basin and deduced late Paleocene to early Eocene age based on the presence of *Apectodinium* sp. Also composition of species of dinoflagellates like *Kallosphaeridium, Ifecysta perchyderma,* and *Hafnaisphaera septata* indicate a marginal marine environment, also the abundance of fresh water algae *Derbaya glyptosperma* suggest contribution from fresh water environment. Earlier studies reported the age of the Araromi Formation around Ifon as Late Maastrichtian-Paleocene through the use of diagnostic palynomorphs and also infer the paleoenvironment whether they are different from those earlier proposed for the Formation from other locations by earlier workers.

The findings would broaden the knowledge of the stratigraphy of the Dahomey Basin and further highlight the preponderance of palm pollen in the Late Cretaceous-Early Tertiary of Nigeria to confirm the provenance of the palm province in Nigeria.

Geology of the Study Area

The Sile well is located in Seme Field, south of Benin Republic (Fig. 1 and Fig. 2)**.** Sile Well which penetrates Cretaceous-Tertiary sediments is located within Block 1, shallow offshore Benin Basin on its border with Nigeria at water-depth of up to 750m. The stratigraphic setting of the Dahomey basin has been described in detail in the works of Adegoke, 1969; Adediran and Adegoke, 1987 to mention a few. These authors have described five lithostratigraphic formations covering the Cretaceous to Tertiary ages. The formations from the oldest to the youngest include Abeokuta Group (Cretaceous), Ewekoro Formation (Paleocene), Akinbo Formation (late Paleocene), Oshosun Formation (early Eocene) and Ilaro Formation (late Eocene) (Fig. 2).

Methodology

Twenty ditch cutting samples ranging from interval 1340-1720m were used for the biostratigraphic studies. The Sile Well reached a total depth of 2000m (Fig. 3). It comprises four lithologies, which include sandstone, shale, limestone and shaly limestone.

Palynological slides were prepared for palynological analysis. Twenty shale samples were selected and taken to Mosunmolu Limited, Lekki, Lagos State for palynological analysis. A weight of 20 g of each sample is put in beakers and initially given a hot hydrochloric acid (HCl) treatment for removal of carbonates while hydrofluoric acid (HF) then gently added under a fume cupboard to the samples in plastic cups for removal of silicates. The samples were then washed and decanted three times at interval of one hour 1hr to ensure dissolution of the acids and wet-sieved over a 5microns mesh polypropylene sieve.

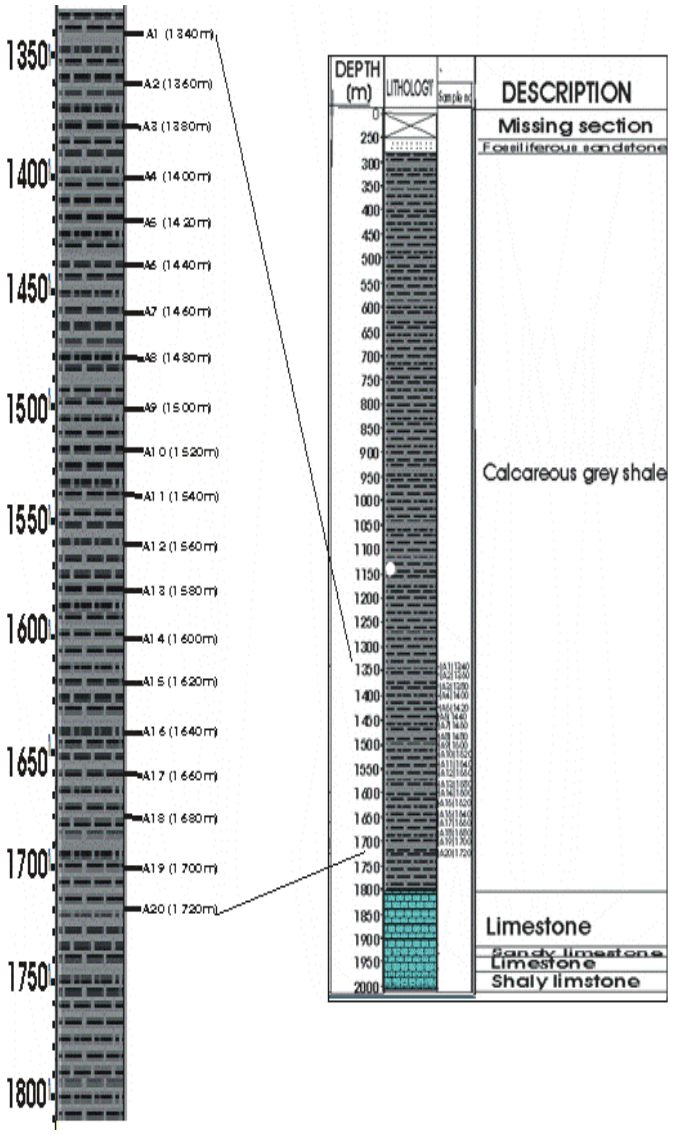

Fig. 3. Lithologic section of Sile Well

The Branson Sonifer 250 was used during sieving to facilitate complete removal of silt and clay particles. The sieved residue was given controlled oxidation using concentrated nitric acid (HNO3). The level oxidation required by each sample is closely monitored under a palynological microscope. The samples were then poured into test tubes and arranged in the centrifuge where it was spinned to aid

fast settling for retrieval of the organic matter. The residue is usually prepared for study as strewn mouths. The mounting medium used is loctite, manufactured by Loctite Corporation USA or Norland Optical Adhesive, cured over UV light. The slides were studied to obtain the palynomorphs (Pollen, spores, dinoflagellates, and fresh water algae.

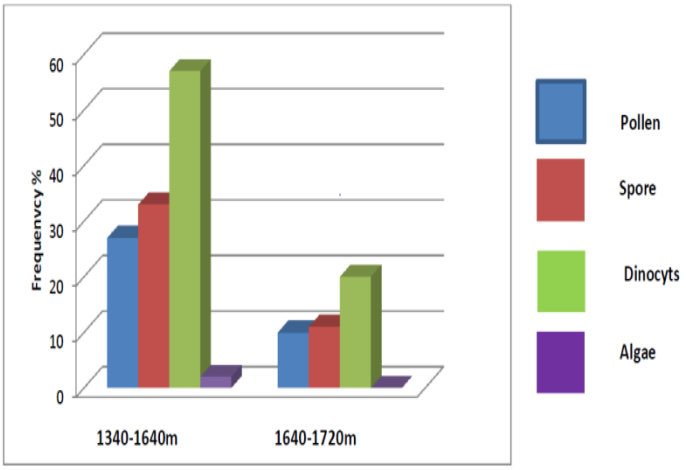

Fig. 4. Histogram of frequency (%) palynomorphs distribution in Sile Well.

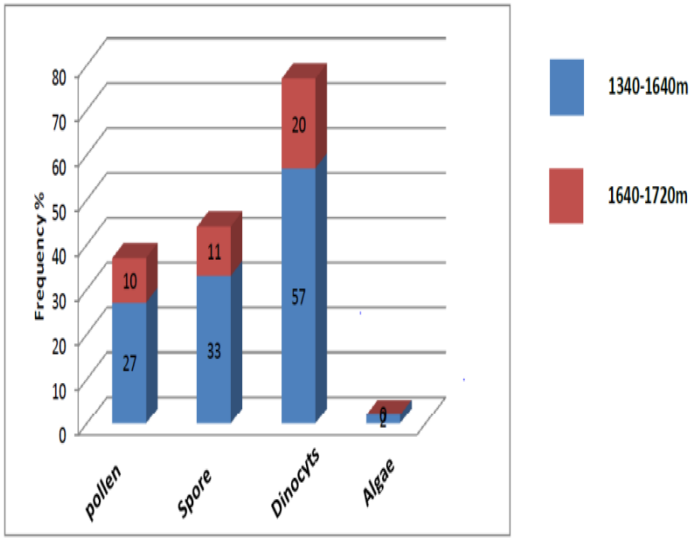

Fig. 5. Frequency distribution plot of palynomorphs in Sile Well.

Results and Discussion

The species recovered as shown in Table 1 include 19 angiosperms pollens, followed by 8 fern spores, 20 dinoflagellates cyst and 1 algae. Histogram chart (Fig. 4) and frequency distribution chart (Fig. 5) were plotted to show the graphical representation of the taxa

The pollen taxa recovered are: *Araucariacites* sp, *Echinate pollen, Inaperturopollenites* sp, *longapertites* sp, *Monocolpites* sp, *Monoporites annulatus, pachydermites diederixi, pollen indeterminate, proxyapertites cursus, psilamonocolpites margvinatus, psilamonocolpites magnoporatus, psilatricolporites* sp, *psilatriporites rotundus, Retibrevitricolporites protrudrens, Retimonocolpites* sp, *Retinocolpites irregularis, sapotaceiodaepollenites* sp, *spinizocolpites echinatus, Tricolporites* sp,

Spore taxa include:

Acrostichum aureum, fungal spores *and* hyphae, *Laevigatosporites* sp, *Monosulcites* sp, *polypodiaceoisporites* sp, *caniga* sp, *Tasmanites* sp, *cyathides minor.*

Dinoflagellates include:

Dinocyst indeterminate, *Leisphaeridia* sp, *Lingulodinum machaerophorum, Nematosphaeropsis* sp, *Operculodium Centrocarpanum, Spiriferites membraneceus, spiriferites pseudofurcatus, Spiriferites ramosus, Spiriferites* sp, *Apectodinum* cf. *homomorphum, Apectodinum* sp, *Cleistosphaeridium* sp, *Lejeunecysta* sp, *Multispinula quanta, Trichodinum* sp, *paleocystodinium* sp, *Andalusiella* sp, *Phelodinum* sp, *Isabelidinum* sp, *Operculodinum* cf. *severinii*

Algae- *Botryococcus braunni*

Table 1. Distribution and abundances of palynomorphs from the studied section.

Sample	No of species		Pollen count abun	% freq	Spore count	% Freq	Dinoflagell	% Freq	Algae	% Freq	Total abund	Total % freq	Paleoenvironment
	Marine	Terrestial											
1 (1340m)	1	6	4	57	1	14	1	14	1	14	6	3	Continental deposit
2(1360m)	35	16	8	16	8	16	35	69	0	0	51	32	Marine influence
3(1380m)	1	4	1	25	2	50	1	25	1	14	5	3	Continental deposit
4(1400m)	3	3	2	33	1	17	3	50	0	0	6	4	Continental deposit
5(1420m)	0	3	0	0	3	100	0	0	0	0	3	12	Continental deposit
6(1440m)	1	3	0	0	3	75	1	25	0	0	4	3	Continental deposit
7(1460m)	1	4	3	60	1	20	1	20	0	0	5	3	Continental deposit
8(1480m)	8	4	3	25	1	8	8	67	0	0	12	8	Marine influence
9(1500m)	1	5	2	40	2	40	1	20	0	0	5	3	Continental deposit
10(1520m)	3	1	0	0	1	25	3	75	0	0	4	3	Marine influence
11 (1540m)	0	6	2	33	4	67	0	0	0	0	6	4	Continental deposit
12(1560m)	3	2	2	40	0	0	3	60	0	0	5	3	Marine influence
13(1580m)	0	3	0	0	3	100	0	0	0	0	3	2	Continental deposit
14(1600m)	1	1	0	0	1	50	1	50	0	0	2	1	Continental deposit
15(1620m)	0	0	0	0	0	0	0	0	0	0	0	0	Barren
16(1640m)	0	3	3	100	0	0	0	0	0	0	3	2	Continental deposit
17(1660m)	0	5	2	50	2	50	0	0	0	0	4	3	Continental deposit
18(1680m)	5	8	2	15	6	46	5	38	0	0	13	8	Continental deposit
19(1700m)	11	1	0	0	1	8	11	92	0	0	12	7	Marine influence
20(1720m)	4	5	3	33	2	22	4	44	0	0	9	6	Continental deposit
TOTAL			37		42		76				158		
			23%		27%		49%		1%			100%	

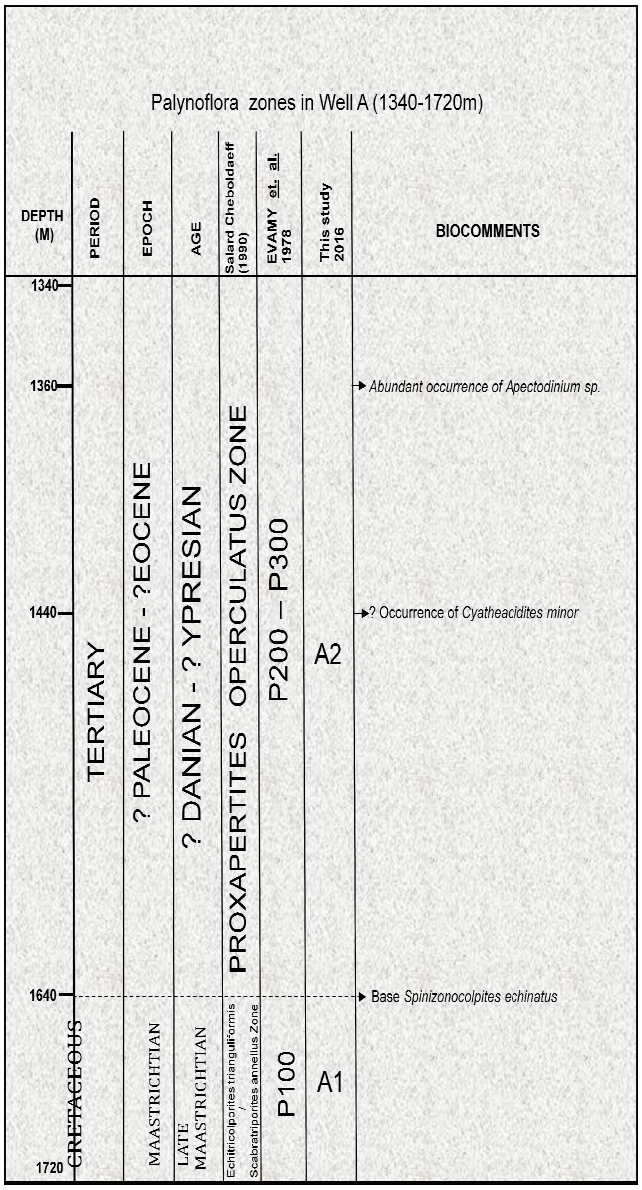

Fig. 6. Palynofloral zones in Sile Well.

Palynozones

Several workers have used palynological data to deduce age and depositional environments of sediments. They include Lawal and Moullade (1986), Ola- Buraimo and Adeleye (2010).

Ditch cutting samples from the Sile Well (1340-1720m) were processed for palynological analysis and interpretations. Petrography observation of the prepared slides show that the studied interval recorded poor quantities and diversity of palynomorphs. The results of the samples studied are presented in the analysis sheets while the order of appearance of important fossil grains and their interpreted palynological zone, age, and paleoenvironment of deposition is presented in the checklist of Figure 6.

Detailed palynological analysis carried out on the Twenty (20) samples of Sile Well (1340-1720m) recorded poor to fair recovery of palynomorphs in term of abundance and diversity. The zonation exercise carried out was compared to earlier works done on Cretaceous sediments in Pan Tropical Areas (Salard cheboldaeff, 1990). Details of the palynological zones recognized are discussed below and shown graphically in the palynology distribution chart of (Fig. 6). However, the erection of biozones is dependent of the evolution, extinction and quantitative occurrence of marker forms present in the sediments (Ola-Buraimo, 2012).

Biozonation (Palynozone A1)

Interval 1640-1720m

Zone: *Echitricholporites trianguliformis* zone

Age: Late Maastrichtian

Diagnosis: The base of this zone is stratigraphically deeper than the last studied sample and as such was not encountered. The top is marked by the base occurrence of *Spinizonocolpites echinatus* identified at 1640m. Other characteristic palynomorphs species recorded within this zone include *Longapertites* sp. *Acrostichum aureum* and *Laevigatosporites* sp. *Leoisphaeridia* sp., *Operculodinium centrocarpum, Andalusiella* sp., *Palaeocystodinium* sp. and

Table 2. Paleoenvironment Interpretation from P.M.I. Value of the Palynomorphs Distribution.

DEPTH	POLLEN	SPORE	DINOCYST	ALGAE	TOTAL	PMI	%POLLEN	%SPORE	%MICROPLANKTON	Paleoennvironment
1340	4	1	0	0	5	0	80	20	0	Fluvial deposit
1360	8	8	35	1	52	194	15	15	69	C/Marine deposit
1380	1	2	1	0	4	25	25	50	25	Fluvial deposit
1400	2	1	3	0	6	75	33	17	50	Fluvial deposit
1420	0	3	0	0	3	0	0	100	0	Fluvial deposit
1440	0	3	1	1	5	20	0	60	40	Fluvial deposit
1460	3	1	1	0	5	20	60	20	20	Fluvial deposit
1480	3	1	8	0	12	160	25	8	67	C/Marine deposit
1500	2	2	1	0	5	20	40	40	20	Fluvial deposit
1520	0	1	3	0	4	150	0	25	75	C/Marinedeposit
1540	2	4	0	0	6	0	33	67	0	Fluvial deposit
1560	2	0	3	0	5	100	40	0	60	Fluvial deposit
1580	0	3	0	0	3	0	0	100	0	Fluvial deposit
1600	0	1	1	0	2	50	0	50	50	Fluvial deposit
1620	0	0	0	0	0	0	0	0	0	Fluvial deposit
1640	3	0	0	0	3	0	100	0	0	Fluvial deposit
1660	2	2	0	0	4	0	50	50	0	Fluvial deposit
1680	2	6	5	0	13	0	15	46	38	Fluvial deposit
1700	0	1	11	0	12	550	0	8	92	Marine deposit
1720	3	2	4	0	9	67	33	22	44	Fluvial deposit

Lejeunecysta sp.*,* are characteristic dinoflagellate cysts recorded in this interval which majorly suggests marine environment of deposition.

This zone is related to the *Echitricolporites trianguliformis/Scabratriporites annellus* zone of Salard Cheboldaeff (1990) zones and the P100 paly zone of Evamy et al., (1978).

Palynozone A2

Depth: (1340-1640m)

Zone: *Proxapertites operculatus* zone

Age: Paleocene- Eocene Paleocene (Danian) - Eocene (Ypresian)

Diagnosis: The base of this zone is defined by the base occurrence of *Spinizonocolpites echinatus*. The top is stratigraphically higher than the first sample analyzed and as such was not encountered. Characteristic palynomorph species recorded within this interval include *Cyathidites minor, Proxapertites cursus, Spinizonocolpites echinatus,* and *Longapertites* sp. amongst others. Dinoflagellate cysts identified in this interval include *Apectodinium homomophorum, Cleistosphaeridium* sp., *Trichodinium* sp., *Nematosphaeropsis* sp. *and Lejeunecysta* sp. amongst others. Higher frequency of land derived spores over the marine palynomorph abundance thus suggests a paralic paleoenvironment.

This zone is correlated with the *Proxapertites operculatus* zone of Salard Cheboldaeff (1990) zones and the P200-P300 composite zones of Evamy et al., (1978).

Paleoecology

Paleoenvironment of deposition deduction can be carried out through different means based on the obtained palynomorph data. A comparison of land derived forms to marine sourced microplankton was carried out. Further data analysis shows that combined pollen and spore frequency percentage is 51%, while dinoflagellate gives 49% (Table1). This

is shown graphically in the frequency distribution chart (Fig. 4, 5) and distribution pattern of palynomorph types and palynostratigraphic sequence respectively. A semi quantitative interpretation technique was also employed to further determine the paleoenvironment of deposition of interval 1340-1720m of this well (Fig. 7). This is referred to as Palynological Marine Index (PMI). The method is dependent on the amount of terrestrially and aquatic derived palynomorphs separately. Helenes et al., (1998) defined PMI as: PMI = Rm / Rt + 1) × 100. This is used to deduce the paleoenvironments of fossil forms in respect of fluvial and marine environment. The range of classification hereby follows >100 =Fluvial environment 100-200 =Fluvial/ Marine Environment, >200=Marine environment.

Where Rm = number of aquatic palynomorphs (Dinoflagellates + Acritarch + Prasinophytes +Foraminifera linings).

Rt = number of terrestrial palynomorphs (Pollen + Spores+ Fungal remains).

The data shows that interval of Sile Well (1340m-1720m) is dominated with terrestrial environment and marine influence. Thus, a predominant fluvial to shallow marine deposit is suggested for the interval.

Occurrence of *Botrycoccus brauniin* samples 1 and 3 which is fresh water algae also suggest freshwater source near marine environment indicating a marginal marine environment. Therefore, paleoenvironment that fluctuate between continental and shallow marine environments which may be referred as paralic environment is suggested for Sile Well which also support the ternary plot of Spore, Pollen and Microplankton (Fig. 8) indicating the depositional environment of the studied samples (Baioumi and Mandur, 2013).

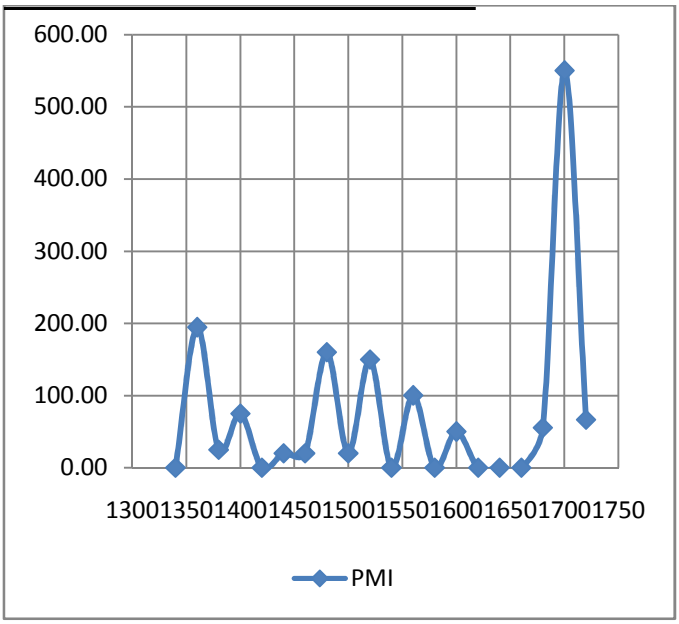

Fig. 7. Palynomorph Marine Index (PMI) chart of Sile Well.

Quantitative interpretation technique applied using Palynomorph Marine Index (PMI) values shows that intervals with PMI value <200 range such as interval 1380, 1400m, 1440m, 1460m,1480m. 1500m, 1520m, 1560, 1600m are equivalent to fluviatile deposits, while PMI value between >200 (1700m) are equivalent to marine deposits.

A general overview of the plot of PMI values against analyzed stratigraphic interval 1340-2000m (Fig. 6) shows that between interval 1340-1480m is characterized by PMI value of about 100, indicative of fluvial deposit; while between interval 1480-1600m shows an alternation of value range between 100-300 suggesting an alternation of continental and marine deposits. The lowermost most part with a depth range be of 1600-1720m is defined by PMI value of 100, suggestive of continental deposit due to dominance of land derived palynomorphs. Therefore, Paleoenvironment that fluctuate between continental and shallow marine environments is suggested for Sile Well. Some photographs of selected microfossils are shown in Plate 1.

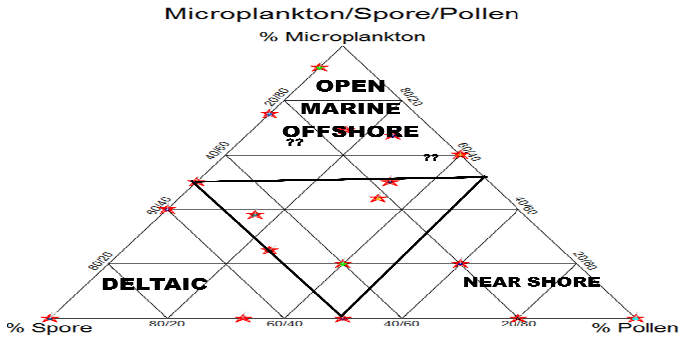

Fig. 8. Ternary plot of Spore, Pollen and Microplankton indicating the depositional environment of the studied samples, (Modified after Baioumi and Mandur 2013).

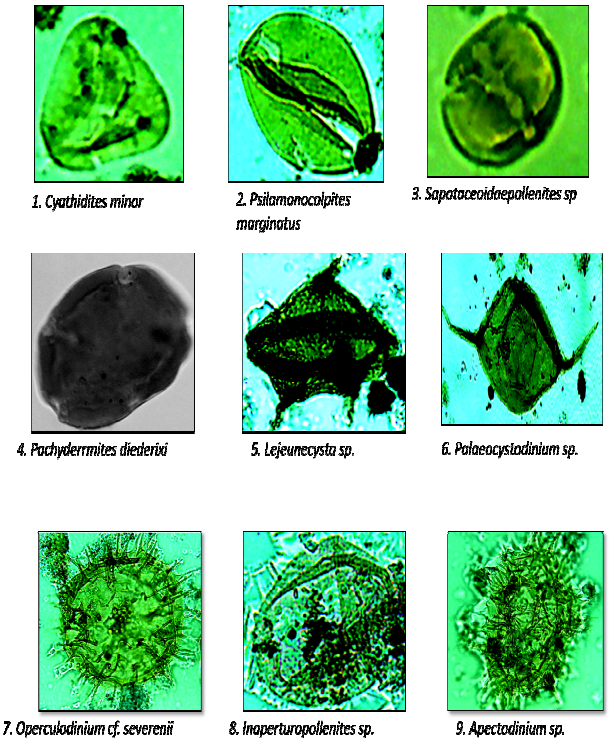

Plate 1. Photomicrographs of palynomorphs of Sile Well (600um).

Conclusions

Biostratigraphic studies were carried out on 20 drill cutting samples retrieved from Sile Well, deep offshore seme basin, Benin republic. They were subjected to palynological analyses to determine their biozonation and depositional paleoenvironments. This section consists from the base to the top of sandstone overlying by shale measuring a total thickness of approximately 2000m. The studied intervals ranged between 1340 and 1720 meters and were sampled at 20-metres intervals for the Palynology.

1. The palynomorphs recovered include 19 Angiosperms (23%), 8 spores (27%), 20 dinoflagellates (47%) and 1 algae species (1%).

2. *Echitricholporites trianguliformis* zone: A1 (1640-1720) dated Late Maastrichtian; characterized by occurrence of *Longapertites* sp, *Acrostichum aureum, Laevigatosporites* sp, and *Leoisphaeridia* sp.

3. The *Proxapertites operculatus* zone: A2 (1340-1640) dated ?Paleocene to ?Eocene and characterized by occurrence of *Cyathidites minor, Proxapertites cursus,* and *Longapertites* sp. Dinoflagellate cysts include *Apectodinum homomophorum, Cleistosphaeridium* sp, *Trichodinium* sp, and *lejeunecysta* sp.

4. Ternary plot of palynomorphs suggest the depositional environment of freshwater through brackish to shallow marine environment,

Biostratigraphy is a valuable tool in oil and gas exploration when it is integrated with other geological and geophysical data sets, such as outcrops, seismic lines or well logs. This paper constitutes a significant contribution to the understanding of the biostratigraphy of Dahomey Basin, which is currently the focus of intensive hydrocarbon exploration activities in Nigeria.

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